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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Two projectile IGES geometry files are provided by ONR. Finite element models have been developed for both projectiles in HyperMesh which will be used in different FEA simulations.
Quarter-symmetric model is used in AutoDyn to simulate DoP experiments on aluminum targets and ceramic-faced aluminum targets with .30cal AP M2 projectile using SPH.
Future work will provide model validation runs based on the DoP experiments described in reference - ARL-TR-2219, 2000.

15. SUBJECT TERMS

.30cal AP M2 Projectile, 762x39 PS Projectile, SPH, Aluminum 5083, SiC, DoP Expeminets, AutoDyn Simulations

16. SECURITY CLASSIFICATION OF: UU			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Shridhar Yarlagadda
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MONTHLY REPORT

JULY 2013

MODELING AND SIMULATION OF CERAMIC ARRAYS TO IMPROVE BALLAISTIC PERFORMANCE

MONTHLY REPORT FOR JULY 2013

- Two projectile IGES geometry files are provided by ONR. Finite element models have been developed for both projectiles in HyperMesh which will be used in different FEA simulations.
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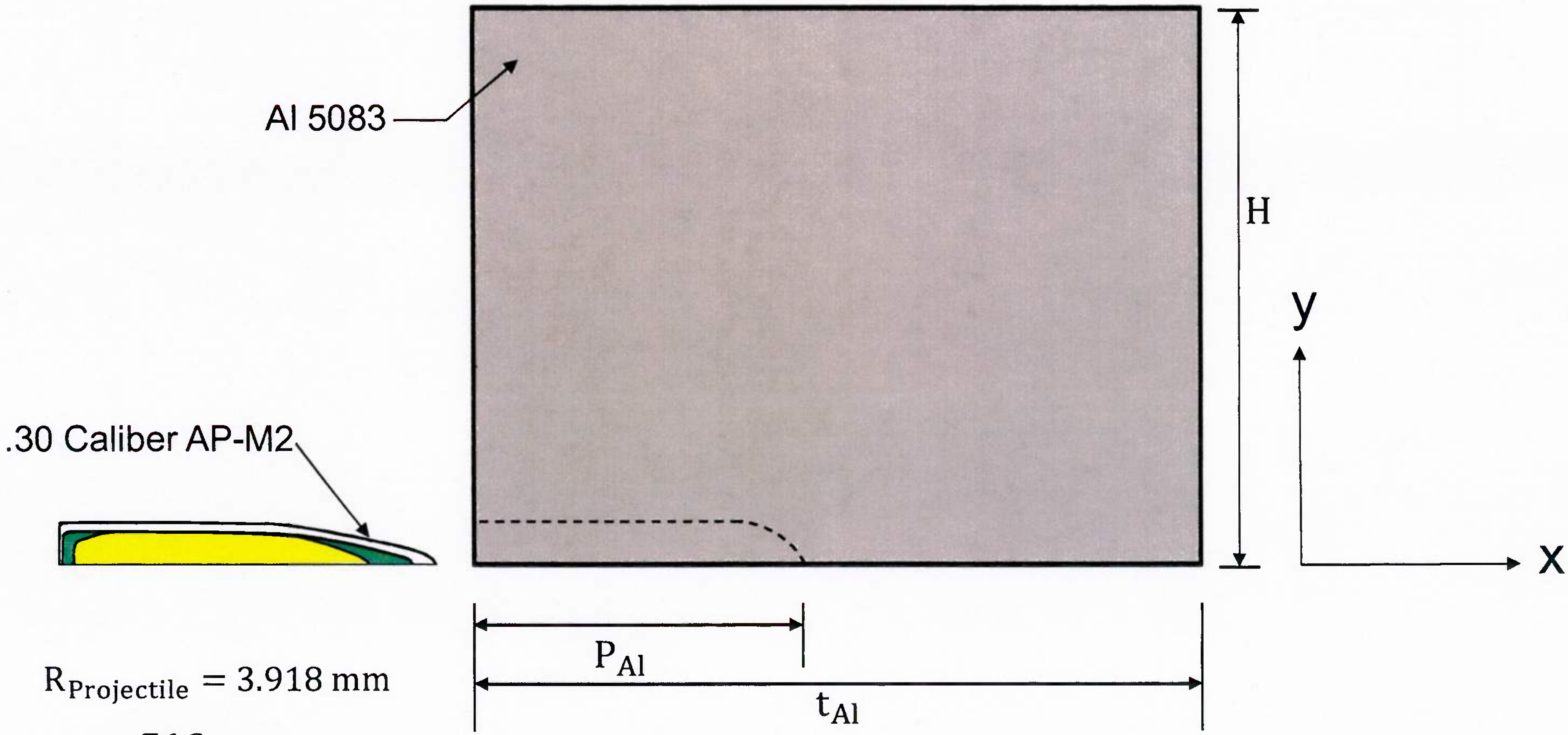
DOP OF .30cal PROJECTILE INTO MONOLITHIC ALUMINUM (Ref: ARL-TR-2219, 2000.)



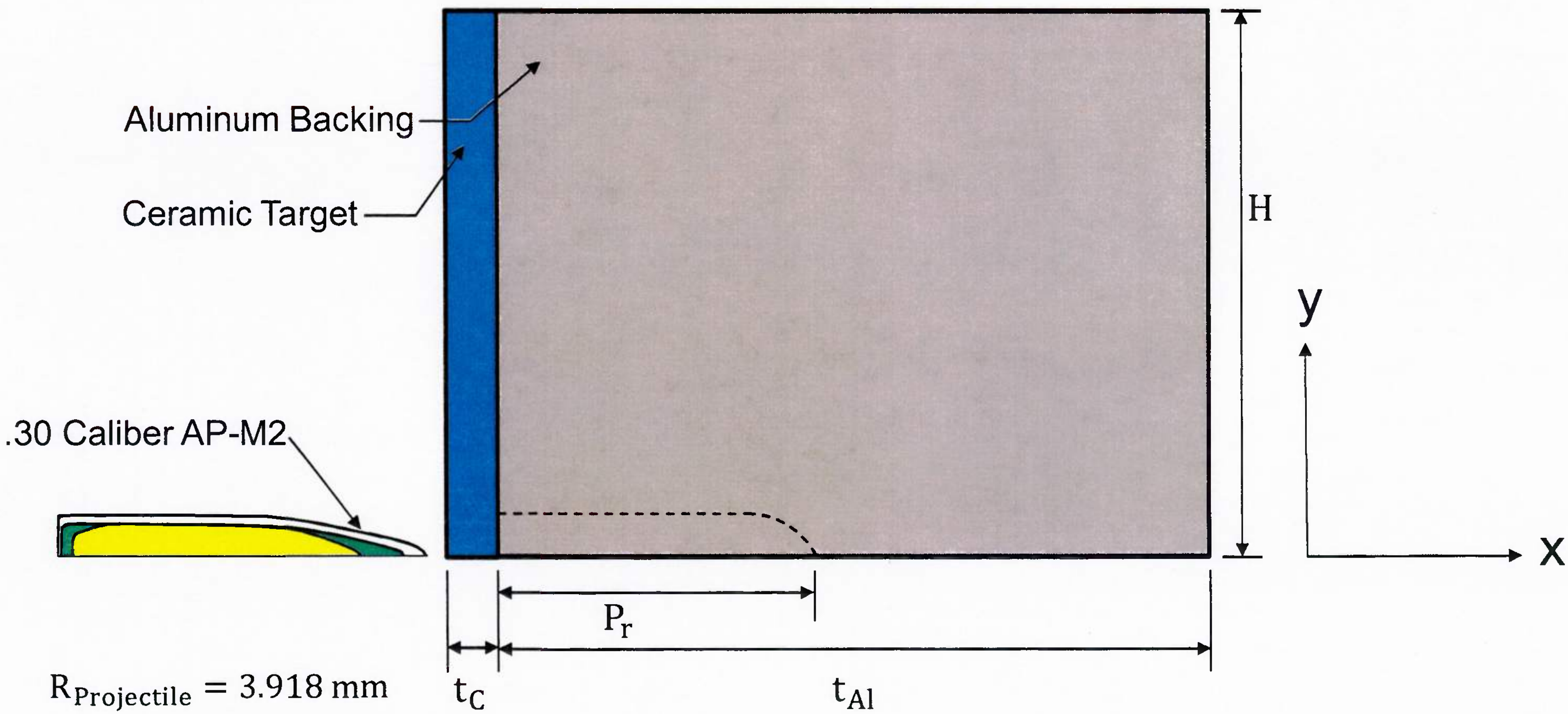
$R_{Projectile} = 3.918\ \mathrm{mm}$

$t_{Al} = 76.2\ \mathrm{mm}$

$H = 20.0\ \mathrm{mm}$

$V_P = 400 - 900\ \mathrm{m/s}$

DOP OF .30cal PROJECTILE INTO CERAMIC-FACED TARGET (Ref: ARL-TR-2219, 2000.)



$R_{Projectile} = 3.918\ \mathrm{mm}$

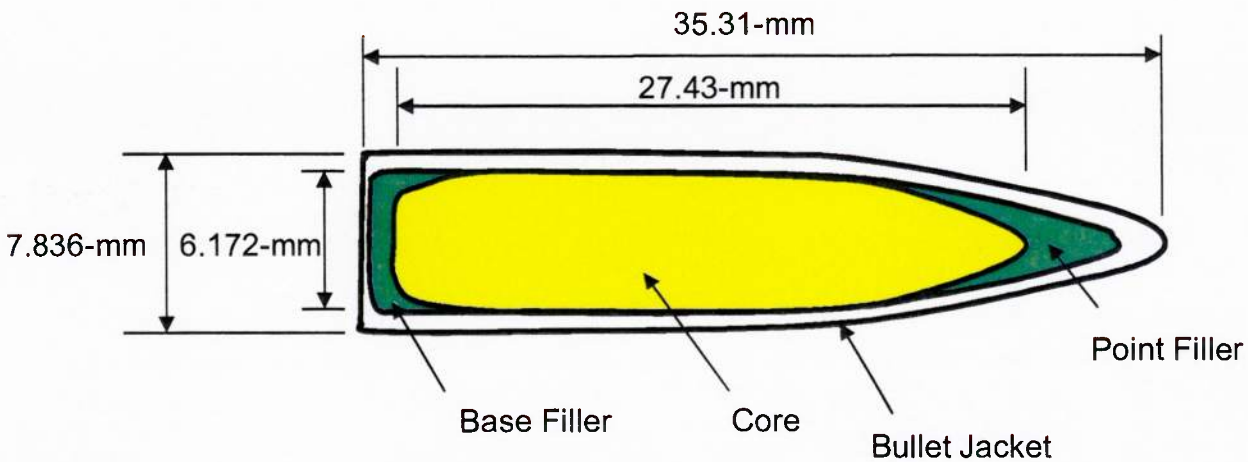
$t_C = 1.25, 2.50, 3.75, 5.00\ \mathrm{mm}$

$t_{Al} = 76.2\ \mathrm{mm}$

$H = 20.0\ \mathrm{mm}$

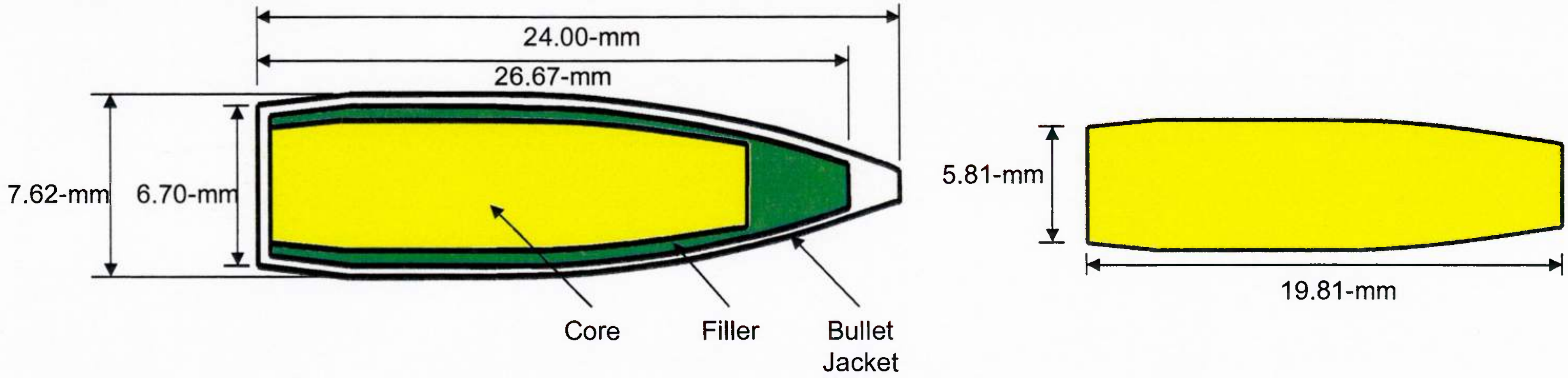
$V_P = 841 \pm 15\ \mathrm{m/s}$

30AP-M2 PROJECTILE MASS PROPERTIES



Component	Material	Weight (g)
Jacket	Gilding Metal	4.2
Core	Hardened Steel - RC 63	5.3
Point Filler	Lead	0.8
Base Filler	Lead	0.5
Total Weight		**10.8**

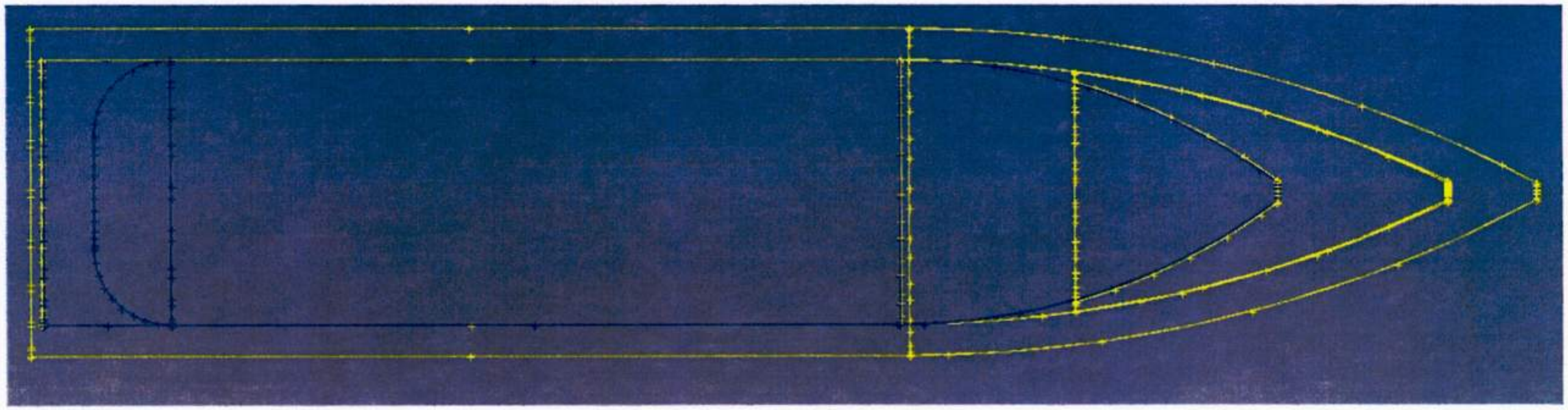
7.62x39 PS PROJECTILE PROPERTIES



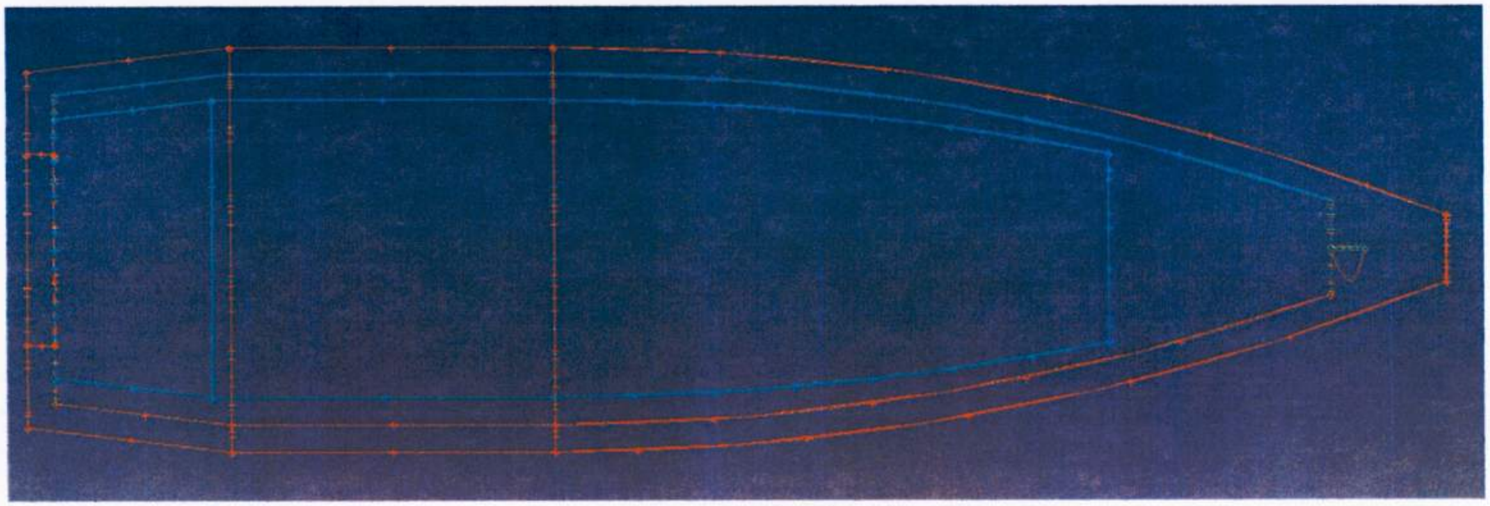
Component	Material
Jacket	Copper-Plated Steel
Core	Steel
Filler	Lead

PROJECTILE GEOMETRIES (Ref: ONR, 2013.)

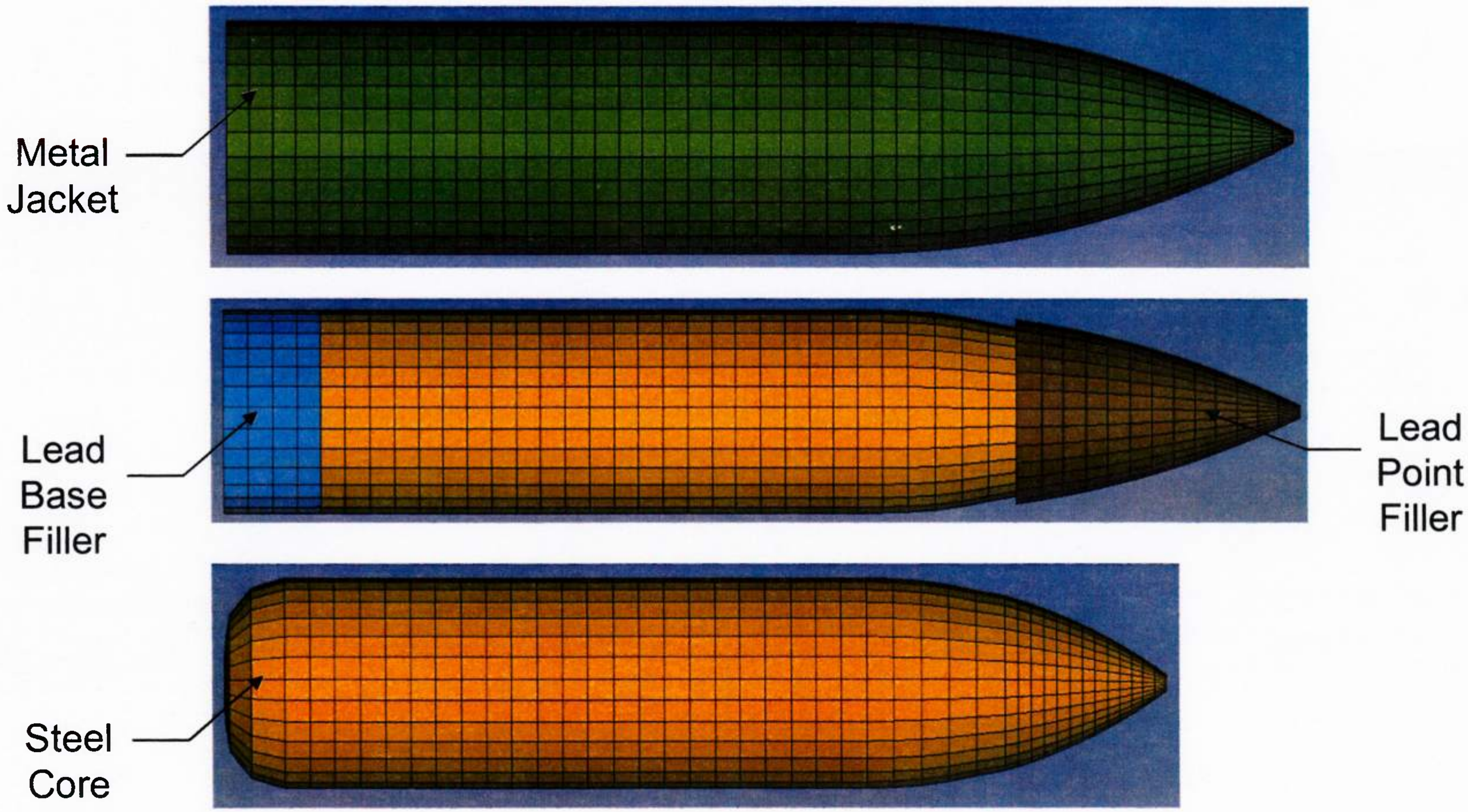
.30cal AP M2



7.62x39 PS



SOLID MODEL OF .30cal AP M2 PROJECTILE



MATERIAL PROPERTIES – Al 5083

Experimental Al 5083

	Al 5083
Density (g/cm^3)	2.65
Tensile Strength (MPa)	377.1
Yield Strength (MPa)	318.5
Elongation (%)	9.3

Ref:
MTL TR-86-14, 1986.
ARL-TR-2219, 2000.

AutoDyn Al 5083

Equation of State	**Linear**
Reference density	2.70000E+00 (g/cm3)
Bulk Modulus	5.83300E+11 (ubar)
Reference Temperature	2.93000E+02 (K)
Specific Heat	9.10000E+06 (erg/gK)
Thermal Conductivity	0.00000E+00 ( )
Strength	**Johnson Cook**
Shear Modulus	2.69200E+11 (ubar)
Yield Stress	1.67000E+09 (ubar)
Hardening Constant	5.96000E+09 (ubar)
Hardening Exponent	5.51000E-01 (none)
Strain Rate Constant	1.00000E-03 (none)
Thermal Softening Exponent	8.59000E-01 (none)
Melting Temperature	8.93000E+02 (K)
Ref. Strain Rate (/s)	1.00000E+00 (none)
Strain Rate Correction	1st Order
Failure	**None**
Erosion	**None**
Material Cutoffs	-
Maximum Expansion	1.00000E-01 (none)
Minimum Density Factor	1.00000E-05 (none)
Minimum Density Factor (SPH)	2.00000E-01 (none)
Maximum Density Factor (SPH)	3.00000E+00 (none)
Minimum Soundspeed	1.00000E-04 (cm/s)
Maximum Soundspeed (SPH)	1.01000E+20 (cm/s)
Maximum Temperature	1.00000E+16 (K)

MATERIAL PROPERTIES - SiC

Experimental SiC

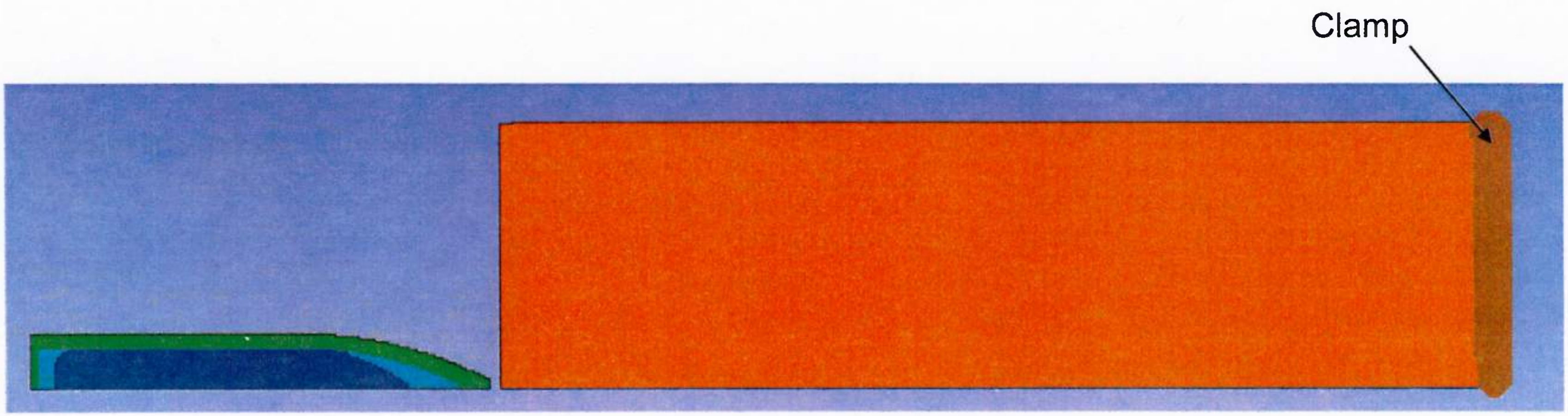
	SiC
Density (g/cm^3)	3.20
Elastic Modulus (GPa)	455
Shear Modulus (GPa)	195
Longitudinal Wave Velocity (km/s)	12.3
Poisson's Ratio	0.14
Hardness (kg/mm^2)	2700
Compressive Strength (MPa)	3410

Ref:
ARL-TR-2219, 2000.

AutoDyn SiC

Equation of State	**Polynomial**
Reference density	3.21500E+00 (g/cm3)
Bulk Modulus A1	2.20000E+12 (ubar)
Parameter A2	3.61000E+12 (ubar)
Parameter A3	0.00000E+00 (ubar)
Parameter B0	0.00000E+00 (none)
Parameter B1	0.00000E+00 (none)
Parameter T1	2.20000E+12 (ubar)
Parameter T2	0.00000E+00 (ubar)
Reference Temperature	2.93000E+02 (K)
Specific Heat	0.00000E+00 (erg/gK)
Thermal Conductivity	0.00000E+00 ( )
Strength	**Johnson-Holmquist**
Shear Modulus	1.93500E+12 (ubar)
Model Type	Segmented (JH1)
Hugoniot Elastic Limit, HEL	1.17000E+11 (ubar)
Intact Strength Constant, S1	7.10000E+10 (ubar)
Intact Strength Constant, P1	2.50000E+10 (ubar)
Intact Strength Constant, S2	1.22000E+11 (ubar)
Intact Strength Constant, P2	1.00000E+11 (ubar)
Strain Rate Constant, C	9.00000E-03 (none)
Max. Fracture Strength, SFMAX	1.30000E+10 (ubar)
Failed Strength Constant, ALPHA	4.00000E-01 (none)
Failure	**Johnson Holmquist**
Hydro Tensile Limit	-7.50000E+09 (ubar)
Model Type	Segmented (JH1)
Damage Constant, EFMAX	1.20000E+00 (none)
Damage Constant, P3	9.97500E+11 (ubar)
Bulking Constant, Beta	1.00000E+00 (none)
Damage Type	Instantaneous (JH1)
Tensile Failure	Hydro (Pmin)

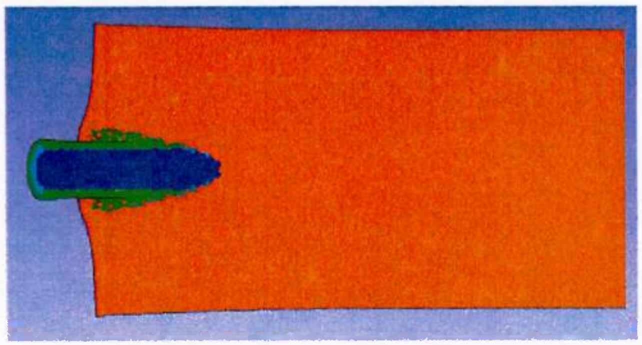
AUTODYN QUARTER-SYMMETRIC MODEL



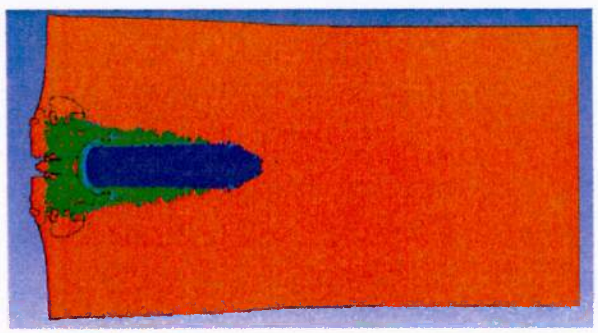
- ❑ Smoothed-particle hydrodynamics (SPH) used for all parts
- ❑ Particle size = 0.30-mm totaling 351k elements
- ❑ Clamp boundary condition used at end of aluminum to secure the target
- ❑ Material strength and damage properties will be varied to validate ARL-DoP data in future

SHOT NO. 2802, V=701.6 m/s

t = 0.0153 ms

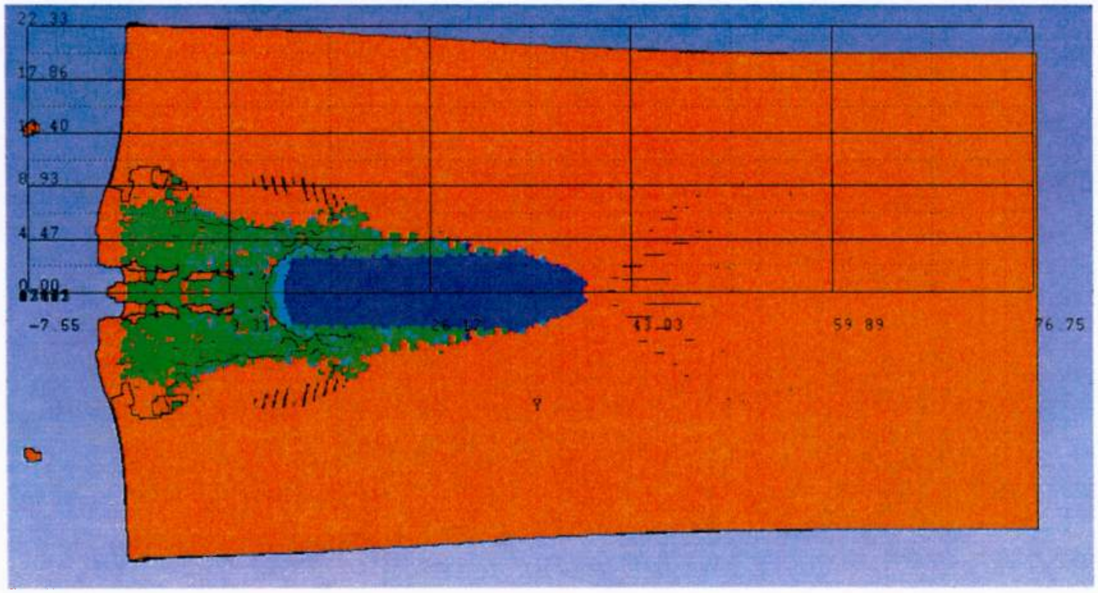


t = 0.0402 ms



t = 0.0715 ms

SHOT NO. 2802, V=701.6 m/s



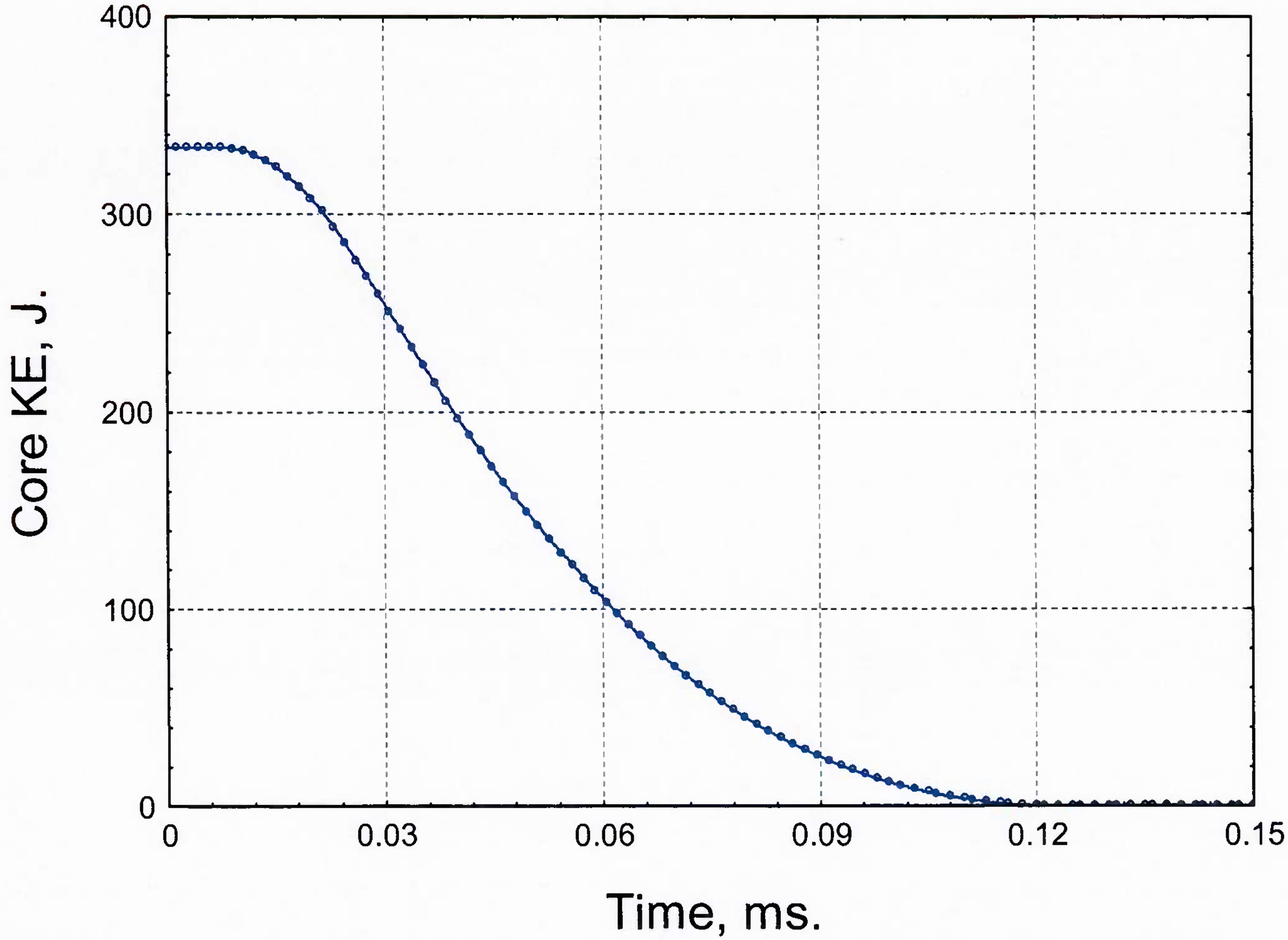
$t = 0.1427$ ms

AutoDyn DOP = 37.785 mm

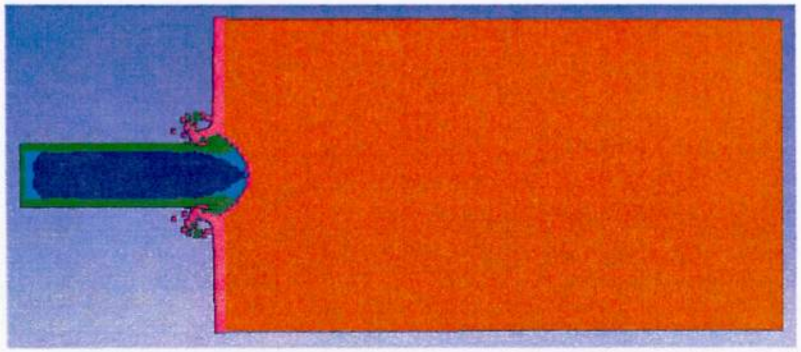
Experimental DOP = 33.8 mm

Conclusion: Reasonable result since yaw and pitch are not considered in AutoDyn run while present in experiment

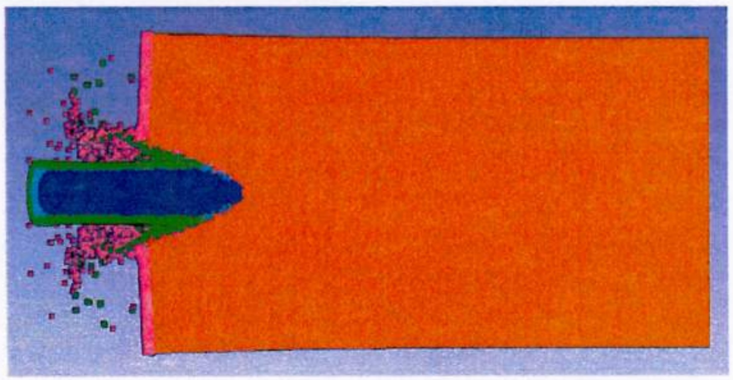
SHOT NO. 2802 PROJECTILE KINETIC ENERGY vs. TIME



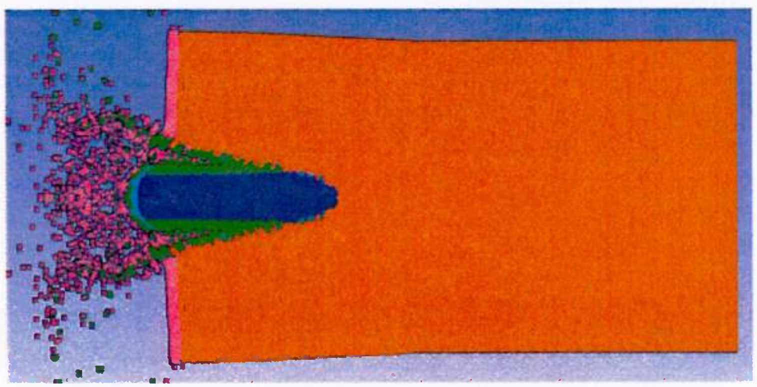
SHOT NO. 3002, V=834 m/s, t_c=1.25 mm



$t = 0.01587$ ms

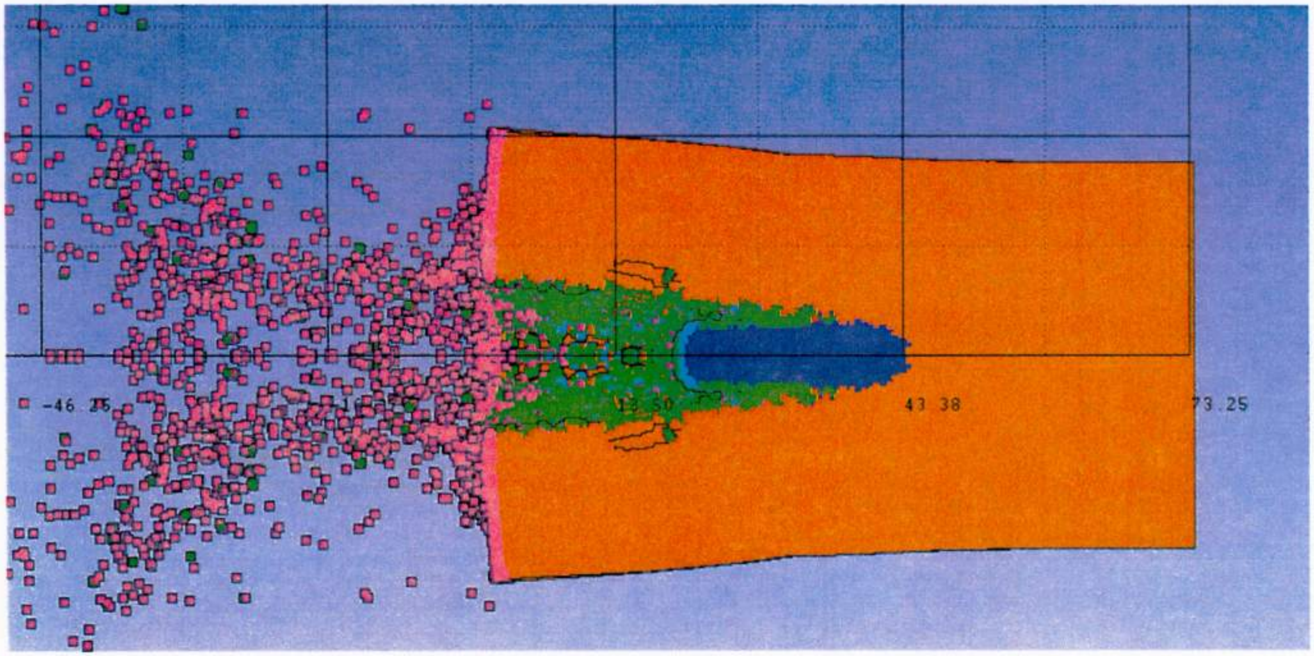


$t = 0.03314$ ms



$t = 0.04902$ ms

SHOT NO. 3002, V=834 m/s, t_c=1.25 mm



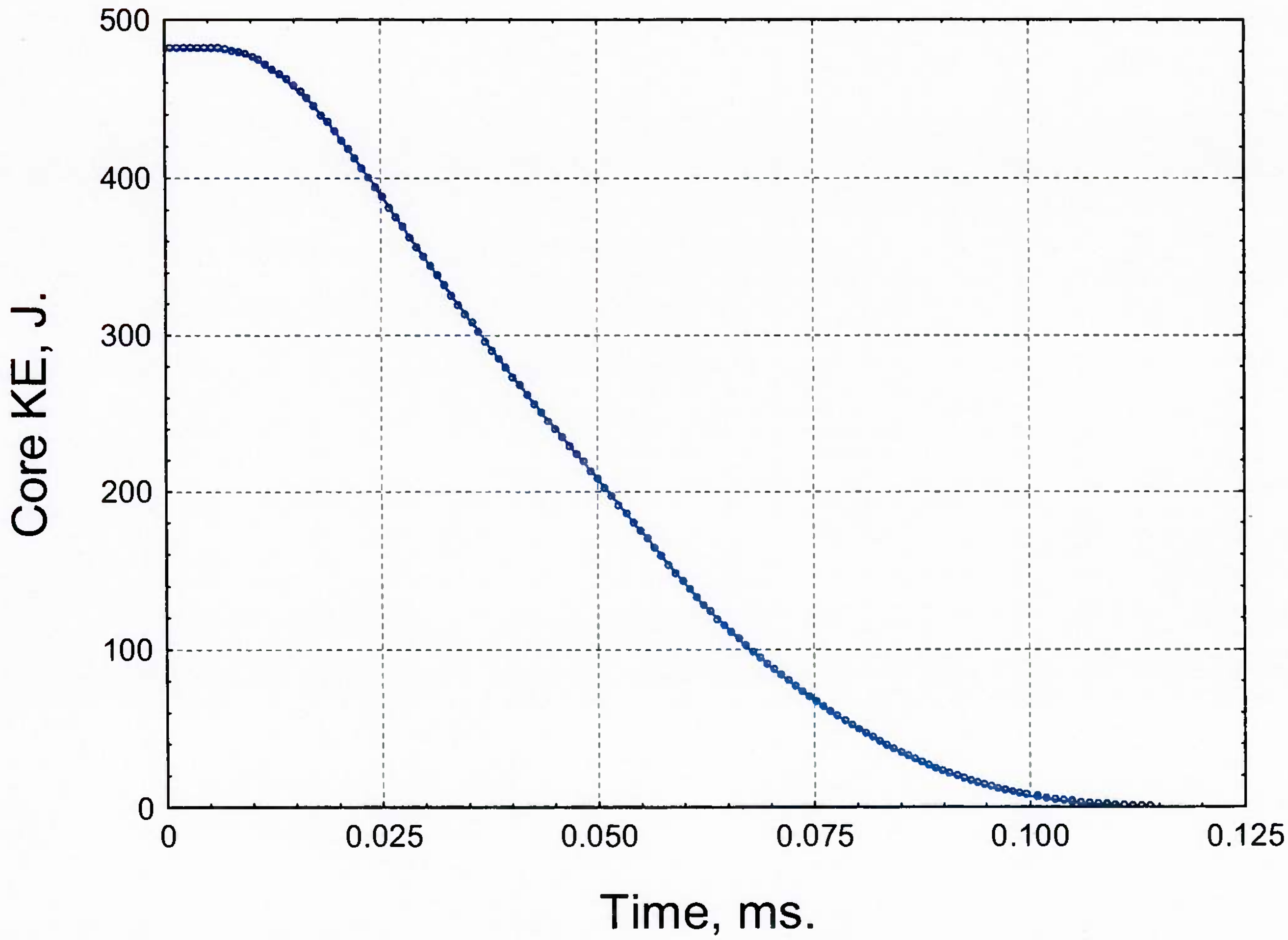
$t = 0.1144$ ms

AutoDyn DOP = 42.38 mm

Experimental DOP = 40.1 mm

Conclusion: Reasonable result since yaw and pitch are not considered in AutoDyn run while present in experiment

SHOT NO. 3002 PROJECTILE KINETIC ENERGY vs. TIME



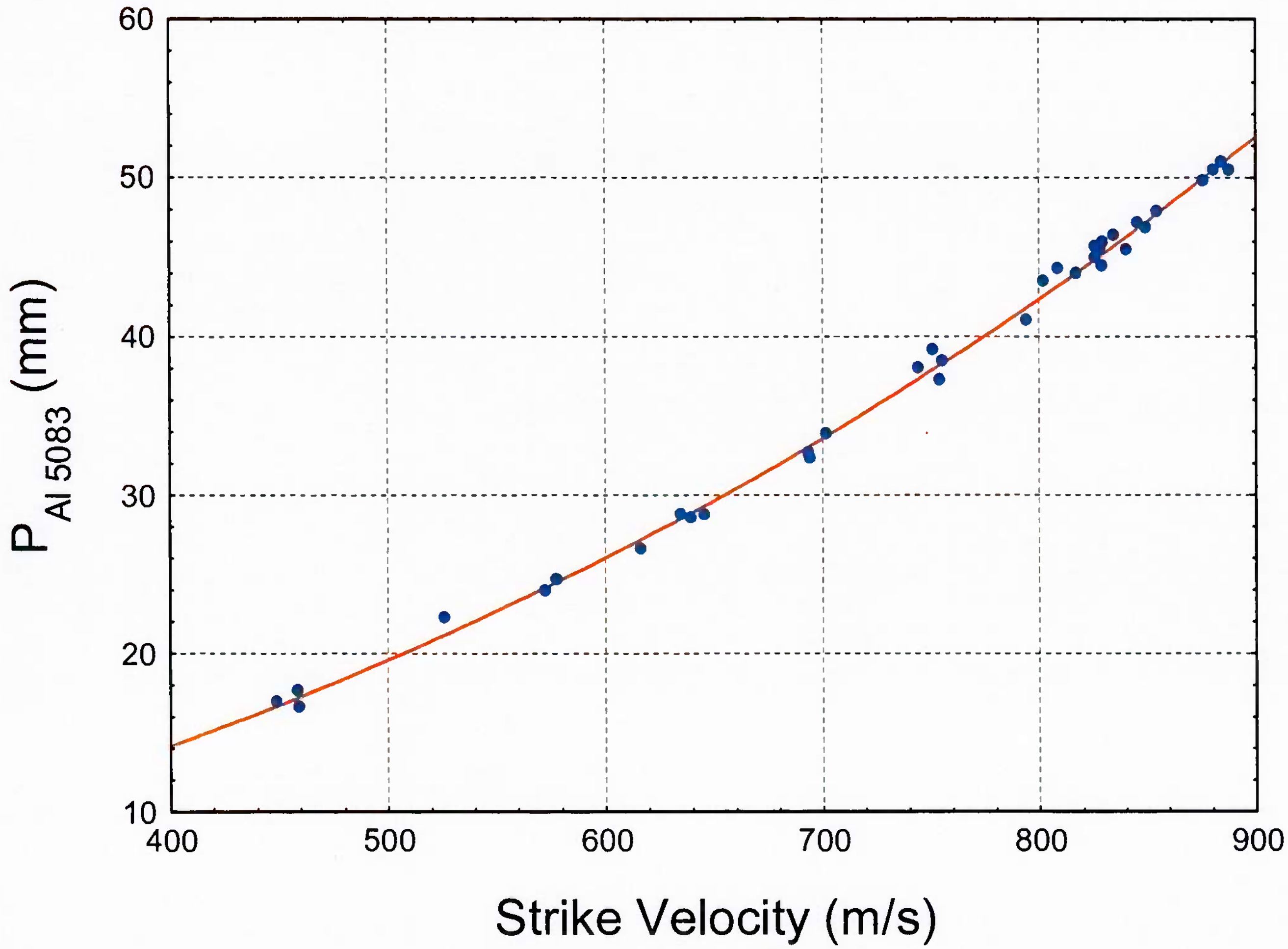
SUMMARY

- Quarter-symmetric model is used in AutoDyn to validate projectile model and ceramic properties using data from ARL-DoP experiments
- Both monolithic aluminum and ceramic-faced aluminum targets match results found in literature with reasonable accuracy
- Mesh size will be reduced and material properties (strength and damage) will be adjusted to improve results
- Further analysis will be done to validate the 7.62x39 PS projectile using a similar approach

Experimental Results from REF: ARL-TR-2219, 2000

ADDITIONAL SLIDES

PENETRATION INTO MONOLITHIC ALUMINUM vs. STRIKE VELOCITY (Ref: ARL-TR-2219, 2000.)



RESIDUAL PENETRATION AREAL DENSITY vs. CERAMIC AREAL DENSITY (Ref: ARL-TR-2219, 2000.)